

RECENT RESULTS FROM THE BNL E787 EXPERIMENT

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Recent results from a rare kaon decay experiment E787 at the BNL-AGS on $K^+ \rightarrow \pi^+ \nu \bar{\nu}$, $K^+ \rightarrow \mu^+ \nu \gamma$, and $K^+ \rightarrow \pi^+ \pi^0 \gamma$ decays are reported.

1 $K^+ \rightarrow \pi^+ \nu \bar{\nu}$

1.1 Theoretical Motivation

The $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ decay is a flavor changing neutral current process induced in the Standard Model (SM) by loop effects in the form of penguin and box diagrams. The decay is sensitive to top-quark effects and provides an excellent route to determine the absolute value of V_{td} in the Cabibbo-Kobayashi-Maskawa matrix. With the constraints from other K and B decay experiments the SM prediction of the branching ratio is $(0.82 \pm 0.32) \times 10^{-10}$, and using only the results on $B_d - \bar{B}_d$ and $B_s - \bar{B}_s$ mixing a branching ratio limit $< 1.67 \times 10^{-10}$ can be extracted¹. New physics beyond the SM could affect the branching ratio².

1.2 E787 Detector

E787^a measures the charged track emanating from stopped K^+ decays. The E787 detector (Figure1) is a solenoidal spectrometer with a 1.0 Tesla field directed along the LESB3 beam line³. Slowed by a BeO degrader, kaons stop in the scintillating-fiber target at the center of the detector. A delayed coincidence requirement (> 2 nsec) between the stopping kaon and the outgoing pion times helps to reject backgrounds of pions scattered into the detector or kaons decaying in flight. Charged decay products pass through the drift cham-

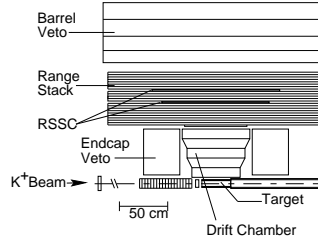


Figure 1. Side view of the upper half of the E787 detector.

ber, lose energy by ionization loss and stop in the Range Stack made of plastic scintillators and straw chambers. Momentum, kinetic energy and range are measured to reject the backgrounds by kinematic means. For further rejection of μ^+ tracks, the output pulse-shapes of the Range Stack counters are recorded and analyzed so that the decay chain $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ can be identified in the stopping scintillator. $K^+ \rightarrow \pi^+ \pi^0$ and other decay modes with extra particles (γ , e , ...) are vetoed by the coincident signals in the hermetic shower counters.

1.3 Result and Prospect

E787 took data on $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ from 1995 to 1998. In the 1995 data set, one event was observed⁴ in the signal region. The new result⁵ from the 1995-1997 data set is shown in Figure2. The same one event was observed and no new events were found in the signal region. The new value for the branching ratio is $(1.5^{+3.4}_{-1.2}) \times 10^{-10}$. Compared to the result from 1995, 2.1 times more kaon ex-

^aE787 is a collaboration of BNL, Fukui, KEK, Osaka, Princeton, TRIUMF, Alberta and British Columbia.

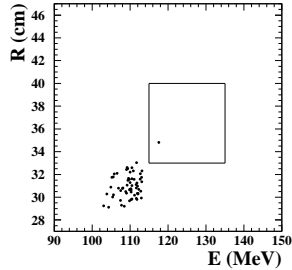


Figure 2. Range vs kinetic energy plot of the final $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ sample from the E787 1995-1997 data set. The box indicates the signal acceptance region.

posure (3.2×10^{12}) and 30% better acceptance are achieved. The background level, 0.08 ± 0.02 events, corresponding to a branching ratio of 1.2×10^{-11} , is improved by a factor of 2.5. The new result provides a constraint $1.07 \times 10^{-4} < |V_{ts}^* V_{td}| < 1.39 \times 10^{-3}$ without reference to the B system.

The kaon exposure in the E787 1998 data set is comparable to 1995-1997, and the analysis is ongoing. The sensitivity for the entire E787 data is expected to reach 0.7×10^{-10} , which is comparable to the SM prediction.

E949⁶ continues the experimental study of $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ at the AGS based on the experience of E787 and is expected to reach a sensitivity of 10^{-11} or less in two to three years of operation. An engineering run of E949 is scheduled for 2001.

2 Photon Detection in E787

The Barrel Veto counter (BL) in Figure 1 detects photons in the study of radiative kaon decays. The counter consists of 48 azimuthal sectors and 4 radial layers, made of lead/scintillator 14 radiation lengths in depth, and covers a solid angle of about 3π sr. The position of BL hits along the beam line is measured with ADC and TDC information from phototubes on both ends of each 2-m long module. The energy and direction of the photons from stopped kaon decays are

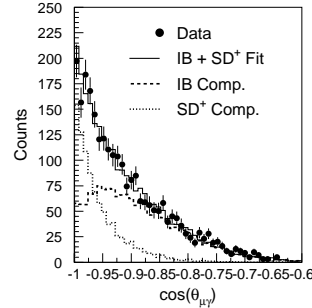


Figure 3. Counts vs. $\cos(\theta_{\mu\gamma})$ of the $K^+ \rightarrow \mu^+ \nu \gamma$ events, and various fits as described in the text.

determined from the offline clustering in the BL and the decay vertex position in the target.

3 $K^+ \rightarrow \mu^+ \nu \gamma$

The decay $K^+ \rightarrow \mu^+ \nu \gamma$ can proceed via internal bremsstrahlung (IB) and structure dependent decay (SD). The latter is sensitive to the electroweak structure of the kaon because the photon is emitted from intermediate states. E787 has made the first measurement⁷ of the SD⁺ component in $K^+ \rightarrow \mu^+ \nu \gamma$ decay, which is proportional to the square of the absolute value of the sum of the Vector and Axial form factors ($|F_V + F_A|$).

The SD⁺ component peaks at high muon and photon energy. With a total kaon exposure of 9.2×10^9 and 1.5×10^6 triggers for $K^+ \rightarrow \mu^+ \nu \gamma$, 2693 events are observed in the signal region where the μ^+ kinetic energy is > 137 MeV and the γ energy is > 90 MeV. The distribution of the opening angle between μ^+ and γ ($\cos(\theta_{\mu\gamma})$) for background-subtracted data, shown in Figure 3 with the Monte Carlo distributions for IB and SD⁺ components superimposed, clearly indicates that the SD⁺ component is present. Detailed fits yield $|F_V + F_A| = 0.165 \pm 0.007 \pm 0.011$, which corresponds to an SD⁺ branching ratio of $(1.33 \pm 0.12 \pm 0.18) \times 10^{-5}$, and a 90% confidence level limit $-0.04 < F_V - F_A < 0.24$.

4 $K^+ \rightarrow \pi^+\pi^0\gamma$

The decay $K^+ \rightarrow \pi^+\pi^0\gamma$ in which the photon is directly emitted (DE) is sensitive to the low energy hadronic interactions of mesons. E787 has performed a new measurement⁸ of $K^+ \rightarrow \pi^+\pi^0\gamma$ decay, with significantly higher statistics than before and improved kinematic constraints using the K^+ decays at rest. The DE component is isolated kinematically with the variable W^2 , which is reconstructed from the opening angle between π^+ and γ ($\cos(\theta_{\pi^+\gamma})$), π^+ energy and momentum (E_{π^+}, P_{π^+}), and γ energy (E_γ) as $W^2 = E_\gamma^2 \times (E_{\pi^+} - P_{\pi^+} \times \cos(\theta_{\pi^+\gamma})) / (m_{K^+} \times m_{\pi^+}^2)$ in the stopped K^+ decays and is directly related to the observables in the E787 detector.

With a total kaon exposure of 1.8×10^{11} and 1.1×10^7 “3gamma” triggers to detect the charged track and three γ clusters in the BL, 19836 events survived all selection cuts including requiring that the kinematically fitted π^+ momentum be between 140 and 180 MeV/c. Figure 4 shows the W spectrum of the signal events. The DE component is measured to be $(1.8 \pm 0.3)\%$ of the IB component, yielding a branching ratio for DE of $(4.7 \pm 0.8 \pm 0.3) \times 10^{-6}$ in the π^+ kinetic energy range 55–90 MeV^b. This result can be understood by purely magnetic contributions in the framework of Chiral Perturbation Theory.

Acknowledgments

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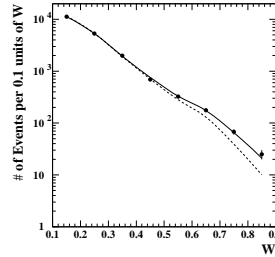


Figure 4. W spectrum of the observed $K^+ \rightarrow \pi^+\pi^0\gamma$ events and best fits to IB+DE (solid curve) and IB alone.

Scientists and for JSPS Fellows, and by the Natural Sciences and Engineering Research Council and the National Research Council of Canada.

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^b Previous experiments used decay-in-flight techniques. The current Particle Data Group average⁹ is $(1.8 \pm 0.4) \times 10^{-5}$.